

WHAT IS CLAIMED IS:

1 1. A minimally invasive surgical instrument comprising:
2 an elongate shaft having a working end, a proximal end, and a shaft axis
3 between the working end and the proximal end;
4 an end effector;
5 a wrist member having a flexible tube and an inner spring which include
6 proximal portions connected to the working end of the elongate shaft and distal portions
7 connected to the end effector, the inner spring being disposed inside an interior cavity of the
8 flexible tube, the inner spring having an axis which is parallel to an axis of the flexible tube;
9 and
10 a plurality of actuation cables having distal portions connected to the end
11 effector and extending from the distal portion through the wrist member toward the elongate
12 shaft to proximal portions which are actuatable to bend the wrist member in pitch rotation
13 and yaw rotation.

1 2. The instrument of claim 1 wherein the actuation cables are disposed
2 inside a hollow interior of the inner spring.

1 3. The instrument of claim 1 wherein at least three actuation cables are
2 connected to the end effector.

1 4. The instrument of claim 1 wherein the proximal portions of the
2 actuation cables are connected to a gimbal plate configured to actuate the actuation cables,
3 the gimbal plate being disposed proximal of the proximal end of the elongate shaft.

1 5. The instrument of claim 1 wherein the actuation cables are disposed
2 between the inner spring and the flexible tube.

1 6. The instrument of claim 5 wherein the flexible tube includes interior
2 axial slots bounded by an external surface of the inner spring to form lumens for receiving the
3 actuation cables.

1 7. The instrument of claim 1 wherein the flexible tube includes a plurality
2 of transverse cut-outs which are generally transverse to the axis of the flexible tube.

1 8. A minimally invasive surgical instrument comprising:

2 an elongate shaft having a working end, a proximal end, and a shaft axis
3 between the working end and the proximal end;
4 an end effector;
5 a wrist member having a flexible tube including an axis extending through an
6 interior surrounded by a wall, the wall of the flexible tube including a plurality of lumens
7 oriented generally parallel to the axis of the flexible tube, the wrist member having a
8 proximal portion connected to the working end of the elongate shaft and a distal portion
9 connected to the end effector; and
10 a plurality of actuation cables having distal portions connected to the end
11 effector and extending from the distal portion through the lumens of the wall of the wrist
12 member toward the elongate shaft to proximal portions which are actuatable to bend the wrist
13 member in pitch rotation and yaw rotation.

1 9. The instrument of claim 8 wherein the wall of the flexible tube
2 includes twelve lumens.

1 10. The instrument of claim 8 wherein each actuation cable is looped
2 around a distal portion of the wall of the flexible tube to extend through two adjacent lumens.

1 11. The instrument of claim 8 wherein the flexible tube includes a plurality
2 of transverse cut-outs which are generally transverse to the axis of the flexible tube.

1 12. The instrument of claim 11 further comprising an outer cover wrapped
2 around an external surface of the flexible tube.

1 13. The instrument of claim 11 wherein the transverse cut-outs comprise
2 alternating layers of cut-outs each having a pair of cut-outs which are disposed opposite to
3 one another, the cut-outs of each layer being oriented in a direction which is spaced by about
4 90 degrees from the cut-outs of an adjacent layer.

1 14. The instrument of claim 13 wherein the transverse cut-outs leave ribs
2 connected between disk portions above and below the ribs, and wherein slits extending
3 generally along the axis of the flexible tube into the disk portions are provided on both sides
4 of the ribs.

1 15. The instrument of claim 8 wherein the flexible tube comprises an inner
2 tube having a plurality of slots oriented generally parallel to the axis of the flexible tube and
3 an outer cover wrapped around the inner tube to form the lumens at the slots.

1 16. The instrument of claim 15 wherein the outer cover comprises an
2 exterior spring.

1 17. The instrument of claim 8 wherein the flexible tube comprises a
2 plurality of springs each disposed around one of the plurality of slots.

1 18. The instrument of claim 8 further comprising an inner spring disposed
2 around the interior of the flexible tube.

1 19. The instrument of claim 8 further comprising a braided cover on an
2 exterior surface of the flexible tube, the braided cover having a first set of wires wound in a
3 clockwise direction between a proximal end and a distal end of the flexible tube and a second
4 set of wires wound in a counter-clockwise direction between the proximal end and the distal
5 end of the flexible tube and interwoven with the first set of wires.

1 20. The instrument of claim 8 wherein the wall of the flexible tube
2 comprises a plurality of axial sliding members which are slidably connected with each other
3 by an axial connection generally parallel to the axis of the flexible tube.

1 21. The instrument of claim 20 wherein the axial connection comprises a
2 tongue and groove connection.

1 22. The instrument of claim 20 wherein each axial sliding member
2 includes a lumen for receiving one of the actuation cables.

1 23. The instrument of claim 20 wherein each axial sliding member is
2 integrally formed with one of the actuation cables as an integrated sliding element.

1 24. The instrument of claim 8 wherein the flexible tube comprises a
2 plurality of axial springs coupled with each other and disposed around a circumference of the
3 flexible tube, each axial spring having coils which overlap with coils of an adjacent axial
4 spring to provide one of the lumens for receiving one of the actuation cables.

1 25. The instrument of claim 8 wherein the flexible tube comprises a wave
2 spring having a plurality of wave spring segments which include high points and low points
3 connected in series along the axis of the flexible tube, the high points of one wave spring
4 segment being connected to the low points of an adjacent wave spring segment.

1 26. The instrument of claim 8 wherein the wrist includes a distal
2 termination disk connected to a distal end of the flexible tube, the distal termination disk
3 being substantially more rigid than the flexible tube.

1 27. A minimally invasive surgical instrument comprising:
2 an elongate shaft having a working end, a proximal end, and a shaft axis
3 between the working end and the proximal end;
4 an end effector;
5 a wrist member having an inner spring which includes a proximal portion
6 connected to the working end of the elongate shaft and a distal portion connected to the end
7 effector, the wrist member having a plurality of annular disks distributed along an axis of the
8 inner spring, the annular disks each having an inside edge connected with the inner spring;
9 and
10 a plurality of actuation cables having distal portions connected to the end
11 effector and extending from the distal portion through the wrist member toward the elongate
12 shaft to proximal portions which are actuatable to bend the wrist member in pitch rotation
13 and yaw rotation.

1 28. The instrument of claim 27 wherein the disks include a plurality of
2 holes through which the actuation cables extend.

1 29. The instrument of claim 27 wherein the disks each include a pair of
2 inner tabs disposed opposite from one another and extending from the inside edge into a gap
3 between coils of the inner spring.

1 30. The instrument of claim 28 wherein adjacent disks are oriented with
2 the inner tabs of one disk disposed about 90 degrees apart from the inner tabs of the adjacent
3 disk.

1 31. The instrument of claim 27 wherein the disks each include an outer
2 mating surface and an inner mating surface for mating between adjacent disks, the outer
3 mating surface of one disk mating with the inner mating surface of the adjacent disk.

1 32. The instrument of claim 31 wherein the outer mating surface and the
2 inner mating surface are generally spherical in shape.

1 33. The instrument of claim 27 further comprising a plurality of elastomer
2 members each disposed between and connected with adjacent disks.

1 34. The instrument of claim 27 further comprising a wrist cover disposed
2 outside of the inner spring and the annular disks.

1 35. The instrument of claim 34 wherein the wrist cover comprises a flat
2 spiral of non-conductive material.

1 36. The instrument of claim 35 wherein the flat spiral includes curled
2 edges which overlap between adjacent layers of the spiral.

1 37. The instrument of claim 35 wherein the flat spiral includes grooves
2 oriented generally parallel to the axis of the inner spring.